THE DRIVE LASER SYSTEM FOR DC-SC INJECTOR*

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Abstract

PKU-SCAF has developed a photoinjector which adopt a 1+1/2 cell super conducting cavity and DC electron gun. We also developed a low cost drive laser system for the photocathode DC gun to provide high average beam current. This laser system include a commercial high repetition rate, ps, all solid-state laser, the home made SHG and FHG, Fourier relay optics and the uniform illumination optics. The test results shows the output power at 266 nm of the laser system is more than 1.2W and got more than 500 μA beam current from CsTe cathode from the DC gun.

INTRODUCTION

FEL needs high quality electron beam. For the advantages of laser driven photo-electron gun, many laboratories choose this approach. In general, the beam design requires the drive laser should be operated with high pulse energy stability, short pulse duration and high timing precise for a long term. Some of the applications need high peak power and for high average current needs the high average power. The drive laser system became complex under those requirements. That means both the laser cost is high and it needs experts to keep the daily maintenance.

A photo-injector which adopts a 1+1/2 cell super conducting cavity and DC electron gun has been developed at Peking University for years [1], [2]. This design is very good for average current acceleration. Peking University RF superconducting acceleration study group is a relative small team. For this reason, we need a good drive laser system to operate, develop this injector, which should be low cost, low maintenance. To study the characters of the injector and exam the physic conceptions, the drive laser also have to fit some special requirements, such as to provide the uniform beam profile.

After investigating the laser market, we choose GE-100-XHP, TBWP, Switzerland, laser as the main part of our drive laser system. According to the requirement of cathode material, CsTe, we develop the second and fourth harmonic generator, beam transport system and designed the beam shaping device. Now, this system is daily operated in the laboratory and the output of the photo-electron gun reaches more than 500 μA with the home made CsTe cathode. In this paper, authors describe the drive laser system and its specifications.

* supported by NSFC (Grand No: 10299021&50132010) and National Basic Research Program (973) (Grand No: 2002CB713602).
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LASER AND SHG/FHG

The Series GE-100-XHP are passively mode-locked diode-pumped solid-state laser systems using semiconductor saturable absorber mirrors (SESAMs). The GE-100-XHP is combined of a semiconductor pump laser and saturable absorber and yields very clean picosecond pulses with exceptional amplitude and phase noise performance. The detail descriptions refer to TBWP documents [3].

There is a built-in nanosecond-response photodiode at the laser head back panel which not only allows the user to confirm pulsed operation but also provides the signal for feedback control. In our system, the CLX-1100 timing synchronization with the phase-locked-loop feedback is used.

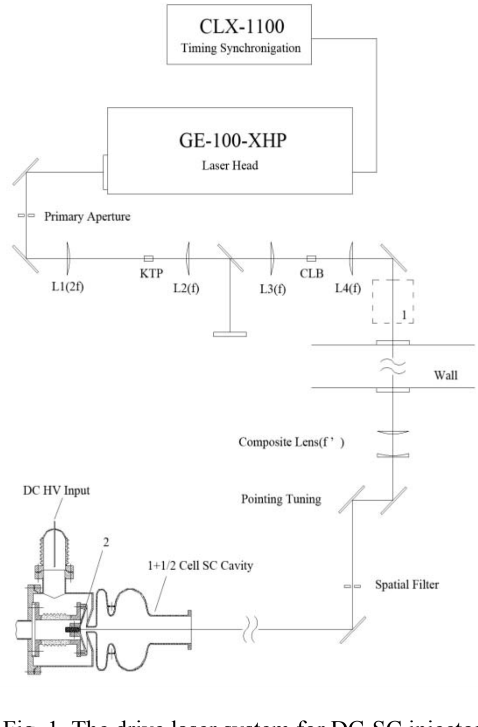

Fig. 1 The drive laser system for DC-SC injector.
In the fig, f = 100 mm f ' = 3400 mm,
"1" is the special flattener, "2" is the cathode

The working function of CsTe requests light wavelength should be shorter than 270 nm. For this reason, we developed SHG and FHG system. Second harmonic generation (SHG) is realized with a critically phase-matched Potassium Titanyl Phosphate harmonic

(KTiOPO4 or KTP) crystal. The fundamental laser (1064 nm) is focused by a lens (focus length is 200 mm) then pass into a 7×7×10 mm KTP crystal cut in the x-y plane for type II. A second lens (focus length is 100 mm) is positioned after the KTP crystal to realize a 6f system to collimate the 532 nm, second-harmonic beam. The fundamental and second harmonic beam are separated by a 45° harmonic separator which reflecting more than 98% 1064 nm light and transmitting more than 95% 532 nm light.

Table 1: The parameters of the laser system

Wave length (nm)	1064	532	266
Power (W)	10	> 4	> 1.2
Pulse Width (ps)	9.9		
Repetition rate (MHz)	81.25		
Power Stability	~ 1%		
Timing jitter (ps)	< 0.5		
Spot size on Target (mm)			~ 3

The resulting second-harmonic beam passes through a lens (100 mm) that focuses it into a 6×5×15 mm CLBO crystal (θ = 62.5°, φ = 90°, type I). A Pellin Broca prism separates the unconverted 532 nm light from the UV beam. To avoid the CLBO crystal damaged by water vapor, it is installed in a home made heating oven. The oven temperature is keen in 105°C.

The maximum 1064-532 nm conversion efficiency is about 50%. After adjusting the tilt of KTP crystal, the maximum UV power has been reached 1042 mW and the 532 nm beam was at 4.35 W. It should be noted that the UV transmission of the AR coating at each surface of the lens is 90% and the UV losses of the Pellin Broca prism are about 10%, a total UV power of more than 1.4 W should be generated . If there is an AR coating of 266 nm on the CLBO crystal surface, the measured power also should be higher.

LASER BEAM TRANSPORTATION AND BEAM SHAPING

The distance from our laser room to the cathode position is about 8 m. The fundamental laser beam divergence is about 1 mrad. After SHG and SHG, the beam divergence is even more, e.g., the walk-off of CLBO is about 1.2°. So, when the drive laser reaches the cathode, the beam spot size will be larger than 100 mm.

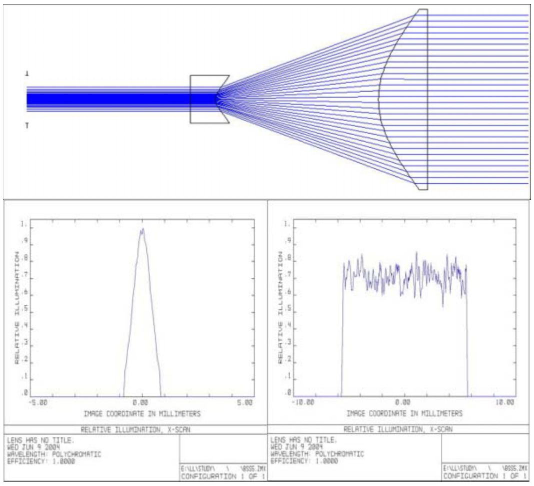

Fig. 2 The two elements beam shaping system

The beam spot size on the cathode surface is required from 2 to 5 mm. If the beam spot is too small, the high power density will damage the cathode. If beam spot is too large, the electron beam profile will be also too larger. To solve this problem, the Fourier relay technique is used. This approach could also maintain a clean transverse mode and improve the beam spot pointing stability.

The primary aperture position is chosen at the beam waist of the fundamental beam, before the SHG crystal. The first lens of focal length 200 mm is placed the distance 200 mm after the primary aperture and 200 mm before the KTP crystal. As the description above, lens L_1 and L_2 are in 6f relation. Then the other lenses are placed in 4f relation. The final is a composite lens of focal length of 3400 mm. By tuning the gap between the convex and concave lens, the beam spot size could be adjusted. The typical UV beam spot size is about 3 mm.

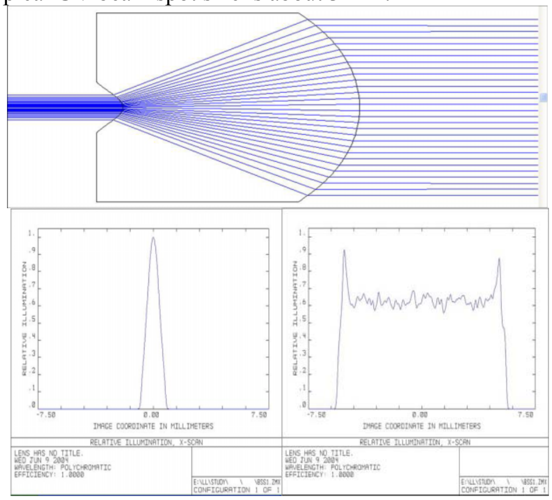

Fig. 3 The single element beam shaping and the simulation result

Beam dynamic simulation result shows that if laser beam spatial profile were uniform, the accelerated beam emittance would be smaller. To prove this achievement, we like to add a spatial flattener in our system. There are numbers approach could produce the uniform beam profile [4], [5]. We have designed both two elements and single element beam shaping system. The simulation results are shown in Fig.2 and Fig.3. From the simulation, there is not much different between two approaches. After further study, we will decide to adopt which one.

CONCLUSIONS

We use a commercials laser, GE-100-XHP, as the main parts to set-up our drive laser. The home made SHG and FHG performed high efficiency. This is a compact and low maintenance system. By use of the Fourier relay technique, the laser transportation is well and the typical beam spot on target is about 3mm. With this system, we have got electron beam current more than 500 μA from the home made TeCs cathode.

We also designed beam shaping system to get the uniform beam profile. The simulation shows both single and two elements system can generate good beam profile. If the spatial flattener is adopted, the Fourier relay system should be redesigned.

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